DOCUMENT RESUME

ED 164 443 SP 012 996

AUTHOR Nelson, Miles A.; Ankney, Paul H.
TITLE An Investigation of the Relationships Between Formal Thinking and Teaching Ability. Research Bulletin Number 2.
INSTITUTION Churchlands Coll. of Advanced Education (Australia).
PUB DATE 77
NOTE 46p.; Paper presented at the Annual Conference, Western Australian Science Education Association (3rd, September 1977)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Abstract Reasoning; *Cognitive Style; *Effective Teaching; Foreign Countries; Intellectual Development; *Logical Thinking; Performance Factors; Planning; *Teaching Skills
IDENTIFIERS Australia

ABSTRACT

It is hypothesized that certain mental structures are related to certain teaching skills. These structures are identified as combinatorial logic, essential to planning lessons, and hypothetical reasoning, an important aid in analyzing lessons. These formal thinking abilities should result in greater improvement during practice and later teaching. It was assumed in testing this hypothesis that there is a relationship between three teaching competencies--planning lessons, analyzing lessons, and manipulation of concrete and abstract ideas to derive generalizations that may be used to improve teaching--and the cognitive style of the teacher. Teacher education students were assessed in individual interviews for formal thinking abilities. Tests consisted of Piaget's colorless liquids, stickman, and conservation of motion tasks, and a paper and pencil test of formal reasoning. Reliability of teaching ability rankings was checked by supervisors who ranked the student over a period of four months. Results of this research did not support the hypotheses that related lesson planning to combinatorial logic and overall teaching effectiveness to formal thinking. Data supported the hypothesized relationship between the ability to analyze lessons and hypothetical reasoning. Samples of the tests used are appended to this report. (JD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED164443

RESEARCH BULLETIN

AN INVESTIGATION OF THE RELATIONSHIPS BETWEEN FORMAL THINKING AND TEACHING ABILITY

Miles A. Nelson
and
Paul H. Ankney

PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Miles A. Nelson

Paul H. Ankney

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM.

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

SP012 996

RB Number 2, 1977.

Churchlands College of Advanced Education

RESEARCH BULLETIN NUMBER 2

AN INVESTIGATION OF THE RELATIONSHIPS BETWEEN FORMAL THINKING AND TEACHING ABILITY

by

Miles A. Nelson and Paul H. Ankney

ISSN 0313-993X
ISBN 909360 24 3
SERIES EDITOR: Milton L. Clark

This Bulletin is produced for limited distribution. It is automatically superseded upon formal publication of the material.

Printed and distributed by
CHURCHLANDS COLLEGE OF ADVANCED EDUCATION
Pearson Street, Churchlands, Western Australia, 6018

1977

ABSTRACT

This study tested the proposition that a formal thinker would become a better teacher, other things being equal. A test of this assumption was made by correlating three formal thinking abilities (combinatorial logic, proportional reasoning, and analysis of variables) with three selected teaching abilities (lesson planning, lesson analysis, and teaching effectiveness).

Formal thinking abilities were assessed in individual interviews consisting of Piaget's colourless liquids, stickman, and conservation of motion tasks, and with a paper-and-pencil test of formal reasoning. Each subject was ranked, using the criteria of effective planning, lesson analysis and effective teaching, by a college supervisor who had observed him/her during a 10 week teaching practice.

The sample, drawn from 198 third-year teacher education students at a College of Advanced Education in Western Australia, was comprised of 30 females and 11 males whose median age was 21 years. To accommodate for variations in applying criteria for ranking subjects, each supervisor's group of assistant teachers was treated as a separate population until it could be shown they were statistically equivalent.

Reliability of the teaching ability rankings was checked by having the supervisors rerank the subjects four months later. Precautions were also taken to ensure reliability of the two Piagetian-task interviewers.

Data obtained from the interview tasks, paper-and-pencil instrument, and supervisor's rankings were correlated using Kendall's tau, and the associated probability levels were tested with the Chi-square statistic. The results did not support the directional hypotheses which related lesson planning to combinatorial logic and overall teaching effectiveness to formal thinking. The data supported the hypothesized relationship between the ability to analyse lessons and hypothetical reasoning.

This paper was presented to the third annual conference of the Western Australian Science Education Association held at the Western Australian Secondary Teachers College in September, 1977.

Dr. Miles A. Nelson is Senior Lecturer in Science Education and Dr. Paul H. Ankney is Lecturer in Science Education at the Churchlands College of Advanced Education.

The authors wish to thank Gilbert M. Burney and William Popejoy for permission to reproduce the *Logical Reasoning Test*.

TABLE OF CONTENTS

		Page
	Abstract	i
	Acknowledgements	ii
1.0	Introduction	1
2.0	Conceptual Basis For The Study	3
3.0	Hypotheses	5
4.0	Operational Definitions	6
5.0	Method	6
6.0	Procedure	11
7.0	Results	12
8.0	Discussion and Conclusions	18
	References	21
	Appendices	23

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN FORMAL THINKING AND TEACHING ABILITY

Miles A. Nelson and Paul H. Ankney

1.0 INTRODUCTION

Educators in teacher training institutions have been looking for predictors of teaching success for decades. Teacher educators are constantly concerned with how well their students will perform after training. A means for identifying individuals who, with appropriate training, will become successful teachers, would increase the efficiency and quality of teacher training programmes, and ultimately result in better quality classroom teaching.

Most attempts to find predictors of future teaching proficiency have used paper-and-pencil tests even though an increasing amount of research has shown little or no correlation between written test results and actual classroom teaching performance (Stein, 1963). Teacher education programmes usually include several screening measures that are administered prior to and during training. Grade point averages, standardized personality surveys, and intelligence tests have also been used with mixed success (McNeil & Popham, 1973; Wilk, Edson & Jyi Wu, 1967; Durflinger, 1963). The efficiency of paper and pencil measures for screening teacher candidates cannot be questioned; however, the validity of these screening measures can be (Ryans & Frederiksen, 1951).

Because teaching is a complex act, a single predictor or a battery of predictors, unless theoretically based, is unlikely to be found. In summarizing the research on teacher personality and effectiveness, Getzels & Jackson (1963) pointed out the lack of significant results and called attention to the need for theoretical guidance. A teacher's grade point average and results on knowledge tests seldom correlate well with his classroom teaching performance. To think significant correlations would exist is to assume that knowing <u>about</u> a job and demonstrating how to <u>perform</u> it are equivalent.

Teaching is performing. Logically then, predictors of teaching success might be found in performance tests. The recent trend of dividing teaching into competency areas is a step in this direction. Locating predictors for each identifiable teaching skill is appealing because such predictors may lead to greater individualization. A trainee found to lack a particular teaching competency might be given specialised treatment to correct the deficiency. This could eventually lead to the identification of teachers who are more proficient in certain types of instruction, e.g. leading discussions, supervising activities, presenting information or themes expositorially, analysing and critiquing written work, etc.

It is possible that individuals possessing certain intellectual abilities are more likely to comprehend and surmount the complexities involved in the teaching act than those who do not possess these abilities. Being able to identify and manipulate instructional variables, for example, would increase the possibility of success in teaching. From Piaget's research we know there are different levels of development in identifying and manipulating variables (Inhelder & Piaget, 1958).

In studying intellectual development, Piaget employs a modified interview method consisting of a series of performance tasks. After initially using paper and pencil tests, Piaget eventually created and used tasks in which the subject could manipulate materials because he believed that logic of action was not the same as logic of words (Flavell, 1963). Using such tasks, Piaget has presented a picture of intellectual development in which an individual learns to handle complex tasks by casting them into mental propositions and then manipulating these to solve a problem.

The mental structures and levels of intellectual development identified by Piaget and measurable by performance tasks are conceivably related to teaching skills. These, in turn, might be used to forecast an individual's chances of success in teaching. This study was undertaken to explore this possibility.

2.0 CONCEPTUAL BASIS FOR THE STUDY

This research is based on the assumption that formal thinking capabilities are related to teaching abilities. Thus, a formal thinker might reasonably be expected to be a better teacher, other things being equal, than a concrete thinker. And conversely, a highly successful instructor is more likely to be formal operational.

What indications are there to suggest a relationship between formal thinking and teaching competencies? At least three teaching competencies can be linked to aspects of formal thinking. These are planning of lessons, analysis of lessons, and manipulation of concrete and abstract ideas to derive generalizations which may be used to improve teaching.

Planning requires such skills as identifying, considering and selecting various means for attaining educational objectives. Research by Inhelder and Piaget (1958, Chapter 7) determined that certain cognitive structures enable formal thinkers to mentally manipulate propositions. One such structure, known as combinatorial logic, makes it possible to identify a wide range and combination of factors from which hypothetical relationships can be established and tested. Individuals not possessing fully operational combinatorial logic fail to identify all possible combinations. In addition, the combinations formed are generally random and limited to only two factors. Teachers possessing fully developed combinatorial logic structures are likely to develop comprehensive plans for presenting a given concept or lesson, particularly if they recognize several alternative methods for doing so. It is postulated that experienced observers such as college supervisors of practice teaching, will be able to identify student teachers who plan their lessons comprehensively.

Hypothetical reasoning, an important attribute of formal thinking permits individuals to extend their thinking well beyond reality (Inhelder and Piaget, 1958, Chapter 8). Children's thinking is essentially tied to their concrete experiences. Many adolescents, however, are able to hypothesize about events not possible in reality.

Teachers often employ hypothetical reasoning, if they possess the capability, in analyzing the outcomes of their instruction. After teaching a given lesson, a teacher may say to himself "If I change this next time, then these things might happen." Such "if-then" thinking is one type of hypothetical reasoning, and the utilization of it may significantly improve subsequent lessons.

General relationships between formal thinking and teaching abilities can also be inferred. For example, individuals using formal thought have decided advantages over concrete thinkers when it comes to learning new information, even if they are nearly as unsophisticated as children in the discipline being learned. Ausubel (1964) believes this is because they are able to draw upon various transferable elements of their overall cognitive structures and experiences, and are able to function on an abstract level more quickly. Since formal thinkers are capable of formulating and manipulating abstractions, they learn efficiently. Evidence of this is their rapid grasp of complex concepts presented in lectures and advanced writings. College students who are formal thinkers probably obtain wider comprehensions of the ideas presented during their college programmes. In addition, formal thinkers are better able to perceive underlying meanings from situations observed directly (as in the classroom), and to utilize these to good advantage. Teachers possessing these capabilities might be expected to improve their teaching more quickly as they gain more classroom experience. On the other hand, teachers operating on a concrete operational level would not profit significantly from more teaching experience.

These arguments are based on several assumptions:

(1) *Not every teacher possesses fully developed combinatorial logic and hypothetical reasoning structures.* This assumption was tested by assessing the extent to which these structures are present in a population of practice teachers.

(2) *If the structures are present they will be used in teaching.* Evidence about this assumption was supplied by the college supervisors of the practice teachers who looked for differences in their supervisees' planning and analysis abilities and whether these differences correlated positively with the ability of the supervisees to use combinatorial logic and hypothecial reasoning.

(3) *The amount of experience in planning and analyzing is roughly equivalent from teacher to teacher.* Preservice teachers having the same level of training have approximately equal experiences in planning and analysis of lessons. One uncontrollable factor was the amount of incidental planning and analysis, i.e. experience preservice teachers have had when informally instructing siblings, their own or other children and the extent to which they plan and analyse within their daily activities.

(4) *The criteria given to the college supervisors for rating planning and analysis of lessons will be applied similarly from supervisor to supervisor.* There was no check on this assumption; however, each supervisor's group of assistant teachers was treated as a separate population.

The conceptual basis for this study lies in the theoretical arguments given above which suggest that certain mental structures assessable by Piagetian tasks are related to certain teaching skills. The authors suggest that combinatorial logic is essential to planning for instruction; hypothetical reasoning is an important aid in analysing lessons; and formal thinking abilities should result in greater improvement during practice and later teaching.

3.0 HYPOTHESES

H_1 : There is a positive correlation between an assistant teachers' developmental level of combinatorial logic and his/her peer group position when ranked by the same college supervisor on the criteria of effective planning.

H_2 : There is a positive correlation between an assistant teachers' developmental level of hypothetical reasoning and his/her peer group position when ranked by the same college supervisor on the criteria of ability to analyze lessons.

H_3 : There is a positive correlation between an assistant teachers' intellectual developmental level and his/her peer group position when ranked by the same college supervisor on the criteria of teaching effectiveness.

4.0 OPERATIONAL DEFINITIONS

Developmental level of Combinational logic:	Score obtained on the Piagetian "Colourless liquids" task.
Developmental level of Hypothetical reasoning:	Score obtained on the Piagetian "Conservation of Motion on a horizontal plane" task.
Intellectual developmental level:	Total score obtained on three Piagetian tasks: colourless liquids, conservation of motion on a horizontal plane, and stickman task.

5.0 METHOD

5.1 Sample

One hundred and ninety eight third year assistant teachers attending an Australian College of Advanced Education were observed by five college supervisors. Although criteria for observing and evaluating teaching performance are established, their application could vary from one supervisor to the next. To cope with this, each supervisor's group of assistant teachers was treated as a separate population. From each population 10 subjects were randomly drawn and asked to participate in the study. This sample size permitted some attrition. The final sample was comprised of 30 females and 11 males whose median age was 21 years. The exact number in each population and sample is given in Table 1.

TABLE 1

POPULATION AND SAMPLE SIZES

	Population					
	1	2	3	4	5	Total
Population Size	37	46	14	44	57	198
Sample Size	9	8	8	8	8	41

5.2 Instrumentation

To assess the development of the psychological structures postulated to have an effect on teaching performance, three

Piagetian interview tasks and the *Logical Reasoning Test* (Burney, 1974) were administered. (See Table 2) These tasks were selected on the basis of their administrative ease and their relationship to the selected teaching skills. A paper-and-pencil test of formal thinking, the *Logical Reasoning Test* (Burney, 1974) was also given to all subjects because such tests are sometimes more reliable than performance tasks and are easier to administer. If the validity of the *Logical Reasoning Test* is similar to the validity of the Piagetian tasks, it would clearly offer savings in time when mass and periodic testing are attempted. By administering this instrument along with the three tasks described below, the authors also obtained further evidence regarding its predictive validity.

TABLE 2

Hypothesized Relationship between three Piagetian Tasks and selected teaching skills.

Piagetian Task	Teaching Skill
1. Stickman Figure (Proportional thinking)	
2. Colourless Liquids (Combinatorial logic)	Planning
3. The Conservation of Motion in a Horizontal Plane (Propositional thinking)	Analysis of Teaching

STICKMAN TASK This task is used to asses proportional thinking and the concept of ratios. Subjects are shown pictures of two stickmen, one being two-thirds the height of the other. The tall stickman measures six large paperclips high, and the short stickman is four large paperclips high. The subject is asked to measure each stickman with a chain of large paperclips and note the results. The large clips are replaced with a chain of small paperclips and the student is asked to measure only the tall stickman. The experimenter then asks "How tall is the short stickman in small clips?" Karplus, *et. al* (1975) utilized this task, and after an extensive analysis of their subjects' responses, identified four response categories. The typical response categories and their assigned point values are given in Table 3.

TABLE 3

Response Categories for the Stickman Task and Assigned Point Values.

Point Value	Criteria
1	Intuitive: The explanation does not make use of all the data or it is used haphazardly.
2	Additive: The explanation focuses on a single difference and solves the problem by addition.
3	Transitional: The explanations show only partial proportional reasoning.
4	* Ratio: The explanation uses a proportion without concrete aids.

*To be classified as formal on this task a ratio response had to be given.

COLOURLESS LIQUIDS TASK This task assesses combinatorial thinking and systematic procedure, both attributes of formal thinking. Five colourless, odourless,liquids are presented to the subject:

Jar 1	dilute H_2SO_4 sulphuric acid (1:10)
Jar 2	distilled H_2O
Jar 3	dilute H_2O_2 hydrogen peroxide (3:97)
Jar 4	dilute $Na_2S_2O_35H_2O$ (sodium thiosulphate) (10 grams per litre H_2O)
Jar G	dilute KI (potassium iodide) (5 grams per litre H_2O)

A small beaker containing liquids from Jars 2 and 3 and another beaker containing liquid from Jar 2 only are shown to the subject, but the contents are not revealed. Several drops from Jar G are put into each beaker by the experimenter with an eyedropper and the subject is asked to observe what occurs. When G is added to 1 + 3, a yellow colour results, but G + 2 remains colourless. The subject is told that each beaker contains only liquids from the jars in front of him. He is then asked to obtain the yellow colour. The main criterion of success on

this task is whether the subject employs a systematic procedure as he goes about obtaining the colour. The subject is asked to describe what is being done and what is discovered as he works. This helps the experimenter determine if an orderly process of elimination is being used, and whether the subject can offer evidence to support his contentions. Scoring criteria are given in Table 4.

TABLE 4

Response Categories for the Colourless Liquids Task and Assigned Point Values.

Point Value	Criteria
1	Produce all combinations of 2 1 + G, 2 + G, 3 + G, 4 + G.
1	Produces the colour one way
1	*States 1 + 3 + G are necessary to produce yellow colour
1	*Produces the colour two ways 1 + 3 + G and 1 + 2 + 3 + G.
1	*States that 2 doesn't help to produce the colour or make it lighter yellow
1	*States that 4 prevents or eliminates the yellow colour

*To be classified as formal on this task each of the four asterisked items had to be achieved.

ROLLING SPHERES TASK This task involves a second order formal attribute, conservation of motion (momentum). Small spheres of various sizes and weights are spring launched one at a time on a horizontal track and allowed to roll freely until they stop. Theoretically an object in motion would move with uniform velocity forever due to its momentum, but obviously this does not occur on earth's surface due to friction, air resistance and other factors. Because this concept is not observable under normal conditions, it belongs in the domain of "relatively possible," in Inhelder and Piaget's words. The experimenter demonstrates the apparatus by launching a medium sized sphere. The subject is then asked to predict which spheres will go farther, and give reasons. This process continues through a range of spheres,

with the subject being asked the same prediction and justification questions for each sphere as it is set in motion. In order to reasonably predict how far a sphere will roll before stopping, the subject must recall or "discover" the principle of inertia (momentum). In addition, the subject must identify the variables involved, vary them one at a time, and decide which ones have a significant effect. Nonformal thinkers focus on the causes of motion while formal thinkers identify and manipulate factors which produce cessation of the motion. Formal thinkers also attempt to provide unifying explanations of the factors investigated. Scoring criteria are provided in Table 5.

TABLE 5

Response Categories for the Conservation of Motion in a Horizontal Plane Task and Assigned Point Values

Point Value	Criteria
2	3-4 causes of motion such as weight, size, density etc., identified
1	1-2 causes of motion such as weight, size, density etc., identified
1	*Evidence of a plan
1	*Improved with practice
1 for each cause	*Causes of stopping such as friction, air in resistance, track smoothness, etc.

*To be classified formal on this task, each of the three asterisked items had to be given.

RELIABILITY AND VALIDITY OF PIAGETIAN TASKS Piagetian tasks are assumed to have face validity if presented in accordance with the description given by Inhelder and Piaget (1958). Their validity can also be tested to some extent by analyzing correlations between tasks. If the tasks measure truly unique abilities their intercorrelations should be zero. The reliability of the tasks, however, depends significantly on their administration. Individual interviewers may pose questions and react to subjects' responses differently. To minimize this potential source of variation, a

checklist type recording sheet was developed. Using the checklist the authors conducted Piagetian interviews with about a dozen volunteers in preparation for the actual study. Alternating between interviewer and observer roles, the authors practiced administering the tasks, made suggestions to each other and classified responses to tasks as formal or nonformal after discussion. This was done to ensure a high degree of interviewer consistency and reliability. A recording form was prepared as the study began. Interviewer variance was also minimized by having each investigator administer the tasks to a random half of the sample.

The reliability of Piagetian tasks is also affected by scoring procedures. Using the checklist, subjects' responses were recorded without interruption or classification. Every effort was made to include on the checklist responses indicative of the IIA, IIB, IIIA and IIIB levels, as given in Inhelder and Piaget's (1958) description of the tasks. When questions arose regarding the categorization of responses the matter was discussed and resolved by the two investigators.

THE LOGICAL REASONING TEST A 21 item paper-and-pencil test of formal thinking, based on R.P. Tisher's original instrument (1962) was developed by Burney (1974). This test consists of seven Piagetian tasks translated into a written objective test format. Burney validated the Logical Reasoning Test with a sample of 9th, 11th and 13th grade subjects by correlating scores with those obtained on the Piagetian Task Instrument. Coefficients for the 13th grade sample and total sample were .56 and .85 respectively. Kuder-Richardson formula 20 coefficients for the 13th grade sample and total sample were .53 and .82 respectively.

6.0 PROCEDURE

To obtain a measure of the subjects' ability to plan and analyse their teaching as well as an indication of effectiveness in the assistant teacher program, five college supervisors were each given a list of 10 supervisees randomly selected from those they visited during the previous semester's assistant teacher programme. Each supervisor was asked to compare each assistant teacher to all of

the others on the list using the criteria effective planning. The most effective planner was assigned to rank of 1, the least effective a 10, and so on. Tied rankings were permissible. Each supervisor also ranked the subjects on two other criteria; analysis of teaching performance, and overall effectiveness as an assistant teacher. Four months after completing these rankings, each supervisor was again asked to rank the subjects using the same three criteria. The two sets of ranks were then correlated, using Spearman's Rank Correlation Coefficient (Siegel, 1956) to provide a measure of ranking consistency.

During a four month period, the three Piagetian tasks and the *Logical Reasoning Test* were administered to all subjects. The presentation of the tasks and the written test was made in random order. Average administration time per subject was about 100 minutes. The subject's scores on each task were grouped according to their population and ranked from highest (1) to lowest. Kendall's tau (Siegel, 1956) was used to compute the correlations between supervisor rankings and rankings on the Piagetian tasks.

Since the five subsamples of assistant teachers were drawn from five different populations, each could be considered a replication of the experiment thus providing more validity and pwoer to the results. This was done by showing the samples had the same distribution and thus were representative of the same population. The two-sided K-sample Smirnov test (Conover, 1971, p.322-325) was used for this purpose. Since each sample was representative of the same population, the results from each supervisor's population were considered to be replications of the experiment (Lindquist, 1953, p.46-47; Guilford, 1956, p.248-250). The significance of the five replications was then determined by using the chi-square statistics as computed by the formula $\chi^2 = 2.1n\ (P_1P_2...P_n)$ where the P_n is the probability of the correlation occuring by chance.

7.0 RESULTS

In this section, an examination of the assumptions made in this study is presented along with evidence of the college supervisor's rating consistency and the validity of the three Piagetian tasks. A presentation of the data obtained and their analysis follows.

It was assumed that the mental structures investigated in this study would vary randomly from one population to the next. A check on the validity of this assumption was made using the Two-sided K-sample Smirnov Test. This statistic was applied to the five sample distribution functions for each of the following tests; the Colourless Solutions Task; the Conservation of Motion Task on a Horizontal Plane Task, the Stickman Task, the Logical Reasoning Test, and the Total Performance Score (the sum of the scores on the first three tasks). On the basis of the values yielded by this statistical measure, it was concluded that the five distributions for each individual task were identical. Judgment on the distribution for the total Performance Scores was suspended since the Smirnov test showed significant differences in distributions could have occurred by chance five times out of 100. On the basis of this information, the researchers treated each of the five supervisors' populations as identical for all tasks and each as a single replication of the experiment. Thus, it was possible to conduct the final analysis of the data as though five replications of a single experiment had been made. Using the criteria presented in Tables 3, 4 and 5, the assistant teachers performing formal operationally on each task were identified. These results are presented in Table 6.

TABLE 6

NUMBER OF SUBJECTS CLASSED AS FORMAL
OR NON-FORMAL BY SEX & POPULATION

		Population 1	2	3	4	5	N
Formal	Male	2	1	0	3	1	7
	Female	1	1	2	2	0	6
Non-Formal	Male	0	2	2	0	0	4
	Female	6	4	4	3	7	24

Males classed as Formal	63.6%
Females classed as Formal	20.0%
Total Population classed as Formal	31.7%

The percentages of formal and nonformal thinkers are similar to the findings obtained by Renner and Stafford (1972), and Sayre and Ball (1972).

The consistency of the college supervisor's ranking of the assistant teachers' planning, teaching effectiveness, and analysing abilities was found to be significantly different from zero at the .02 level indicating that more than a chance relationship between the two rankings exists, and that the supervisors' rankings of the assistant teachers using the given criteria were consistent. These correlations are presented in Table 7.

TABLE 7

CONSISTENCY COEFFICIENTS FOR SUPERVISOR
RATINGS OF ASSISTANT TEACHER PERFORMANCE
USING THREE CRITERIA

Supervisor	Planning	Analysis	Total Effectiveness
1	.92	.91	.78
2	.98	1.00	.82
3	.92	.99	1.00
4	.83	.82	.98
5	.99	.95	.98

To what extent did the tasks measure different mental structures? It was argued earlier that if separate structures were measured by each task, the intercorrelations between tasks would be zero. Table 8 presents the means, standard deviations, ranges and intercorrelations for the tasks used in this study.

From Table 8 it can be observed that the performance task's intercorrelations are all at or near zero. However, the intercorrelations of the performance tasks with Burney's Test of Logical Reasoning are non-zero in two of three instances. The scores obtained from Stickman Figures Task correlate with the paper and pencil Logical Reasoning Test. On the other hand, a negative correlation ($r = -.46$) was found between performance on the Conservation of Motion Task and achievement on the Logical Reasoning Test. This indicates that a high score on one measure is likely to be accompanied by a low score on the other. And finally, no correlation at all ($r = .00$) was found between scores on the Test of Logical Reasoning and scores on the Coloured Solutions Task. On the basis of this information it was concluded that the performance tasks do measure different mental abilities. The preliminary analysis presented above demonstrate the validity of the assumptions made in the study. Thus, a test of the three major hypotheses was made.

Kendall's Tau values and their associated probability levels were determined for each of the five populations. These results are presented in Table 9. To determine the significance of the collective results, chi-square values were calculated, and these also appear in Table 9. The collective results do not support the existence of a positive correlation between combinatorial logic and effective planning, nor between intellectual developmental level and teaching effectiveness. The collective results, however, do support the existence of a positive correlation between hypothetical reasoning and analysis of lessons.

In summary, the data obtained from the Piagetian tasks appears to support the existence of three separate mental structures. The supervisors were consistent in their ranking of the assistant teachers on the given criteria. Further, each supervisor's population

TABLE 8

MEANS, STANDARD DEVIATIONS, AND INTERCORRELATIONS FOR THREE PIAGETIAN TASKS AND LOGICAL REASONING TEST

	Coloured Solutions	Conservation of Motion	Stickman Figures	Logical Reasoning	Total Performance
Mean	3.67	4.29	3.49	15.58	11.77
Standard Deviation	1.64	1.22	0.94	2.68	2.68
Range	0-6	1-7	1-4	10-20	2.5-18
Correlations					
Coloured Solutions	-	.04	.37*	.00	.56**
Conservation of Motion		-	.13	-.46**	-.07
Stickman Figures			-	.44**	.56**
Logical Reasoning				-	.24

* Significantly different from zero at .05 level.

** Significantly different from zero at .01 level.

TABLE 9

KENDALL'S TAU AND PROBABILITY LEVEL FOR CORRELATIONS
BETWEEN SUPERVISOR RATINGS AND SELECTED PIAGETIAN TASKS

Supervisor Population	CORRELATIONS							
	Planning Rank and Rank on Coloured Solution Task		Analysis Rank and Rank on Rolling Spheres Task		Effectiveness Rank and Rank on Total Score of 3 Piagetian Tasks		Effectiveness Rank & Rank on Logical Reasoning Test	
1	-.21*	.73†	-.39	.87	.06	.46	.14	.34
2	-.27	.76	.64	.03	.11	.41	-.37	.86
3	-.34	.87	.23	.27	-.11	.59	-.32	.80
4	.29	.24	.35	.13	.15	.36	-.51	.93
5	.19	.36	.50	.09	.41	.11	.42	.11
Test of Collective Results	χ^2	6.38		18.72		11.04		7.37
	p ♯	<.80		<.05		<.35		<.70

* Kendall's Tau

† Probability level for one tailed test

♯ 10df

of æsistant teachers is identical with the others on the variables measured by the Piagetian tasks which enables the researchers to consider each supervisor's ranking on a given criteria as a replication of the experiment. Only the collective results correlating a subject's score on the Conservation of Motion Task with his/her ranking on lesson analysis can be considered more than a chance occurrence.

8.0 DISCUSSION AND CONCLUSIONS

The first hypothesis, that a positive relationship exists between planning as evaluated by college supervisors and combinatorial logic as assessed by the colourless liquids task, is not supported by the obtained results. What reasons may there be for this? Perhaps the planning assistant teachers do is of a different type than the planning needed to achieve all the combinations of the colourless liquids. The planning done during practice teaching might be a linear type -- first this, then this, and then this -- while combinatorial logic is a more branching, consider-all-the-possibilities planning approach. Another plausible explanation for the obtained data might be that each supervisor consistently applied the criteria to rank his assistant teachers but the criteria of effective planning varied from supervisor to supervisor because each had a different idea about what indicates effective planning. A third possibility is that no actual relationship exists between effective planning and the type of planning measured by the Coloured Solutions Task. Perhaps a positive relationship between planning ability and combinatorial thinking, as well as a clearer interpretation of the findings would have resulted if a more precise definition of planning had been given to the supervisors.

The data gathered in this study support the conclusion of a correlation between an assistant teachers' level of hypothetical reasoning as measured by the Conservation of Motion Task, and his/her ability to analyse lesson presentations, as judged by a college supervisor. One possible interpretation of these results could be that they were a chance occurrence. The probability of such a happening is five times out of 100, which is quite small, considering the experiment was replicated five times.

Teacher effectiveness, as judged by the college supervisors, was not found to be correlated with formal thinking as measured by the three Piagetian Tasks and the Logical Reasoning Test. Several explanations for this finding are possible. For example, teacher effectiveness may be too global a term to be assessed reliably. Or, college supervisors may consistently use their own criteria, but these criteria may vary considerably from one supervisor to another.

Earlier in this paper, an analysis using the Smirnov test was reported. This analysis showed each supervisor's population with respect to the total score to be unique enough to cast doubt on the wisdom of considering each supervisor's population as coming from the same population. This would account for the wide variations in correlations. Another explanation of these results might be found in this study's Conceptual Basis Section, where it was stated that formal thinkers should be able to improve more rapidly than concrete thinkers, because of their ability to abstract generalizations from concrete situations. Just because one teacher improves more than another does not mean he is more effective. For example, one assistant teacher may have improved from being ranked fifth to fourth in comparison with other assistant teachers, while another may improve from being ranked ninth to being ranked fifth. The former assistant teacher would be rated as more effective than the latter, even though the latter improved more. A measure of improvement or growth is needed to find out if formal operational teachers do become better teachers more quickly than concrete operational teachers.

Further research into the possible relationship between teaching ability and formal thinking certainly seems warranted on the basis of the findings in this study. The need for several refinements is apparent: assistant teacher supervisors should be given specific and fairly detailed criteria for assessing planning abilities and teaching effectiveness. In addition, growth in teaching abilities should be observed from the first teaching practice through to the final teaching practice. The supervisors in this study were asked to assess planning and effectiveness

based on the final teaching practice only, and this in effect provides essentially a "snapshot view" of the assistant teachers' abilities. Clearer indications of an assistant teacher's potential for growth in teaching abilities would be more evident in long term or periodic assessments.

REFERENCES

AUSUBEL, D. "The Transition from Concrete to Abstract Cognitive Functioning: Theoretical Issues and Implications for Education". Journal of Research in Science Teaching, 1964, 2, p.261-266.

BURNEY, G.M. "The Construction and Validation of an Objective Formal Reasoning Instrument". Unpublished doctoral dissertation, University of Northern Colorado, 1974.

CONOVER, W. Practical Nonparametric Statistics. New York: John Wiley & Sons, Inc.1971.

DURFLINGER, G.W. "Recruitment and Selection of Prospective Elementary and Secondary School Teachers". Review of Educational Research, Vol. 33, No. 4 (Oct. 1963) p.355-368.

EVANS, R.I. Jean Piaget: The Man and His Ideas. New York: E.P. Dutton & Co., 1973.

FLAVELL, J.H. The Developmental Psychology of Jean Piaget. New York: D. Van Nostrand Co., 1963.

GETZELS, J. & JACKSON, P. "The Teacher's Personality and Characteristics" In N.L. Gage (Ed.) Handbook of Research on Teaching. Chicago: Rand McNally & Co., 1963, p.506-582.

GUILFORD, J.P. Fundamental Statistics in Psychology and Education (4th Ed). New York: McGraw Hill Book Co., 1965.

INHELDER, B. & PIAGET, J. The Growth of Logical Thinking from Childhood to Adolescence. Trans. by A. Parsons & S. Milgram. New York: Basic Books, 1958.

KARPLUS, R., KARPLUS, E., FORMISANO, M., & PAULSEN, A. "Proportional Reasoning and Control of Variables in Seven Countries", Report ID-25, Berkeley, California: Advancing Education through Science Oriented Programs, 1975.

LINDQUIST, E. Design and Analysis of Experiments in Psychology and Education. Boston: Houghton Mifflin Co., 1953.

McNEIL, J.D. & POPHAM, W.J. "The Assessment of Teaching Competence". In R.M.W. Travers (ed) Second Handbook of Research on Teaching, Chicago: Rand McNally & Co., 1973. p.218-244.

RENNER, J.W. & STAFFORD, D.G. Teaching Science in the Secondary School. New York: Harper & Row Publishers, 1972.

RYANS, D.G. & FREDERIKSEN, N. "Performance Tests of Educational Achievement" In E.F. Lindquist (ed) Educational Measurement. Washington, D.C. : American Council on Education, 1951.

SAYRE, S. & BALL, D.W. "Piagetian Cognitive Development and Achievement in Science". Journal of Research in Science Teaching, 1975, 12 p.165-174.

SIEGEL, S. Nonparametric Statistics. New York: McGraw Hill Book Co., 1956.

STEIN, G.G. "Measuring Noncognitive Variables in Research on Teaching". In N.L. Gage (ed) Handbook of Research on Teaching. Chicago: Rand McNally & Co., 1963.

TISHER, R.P. "The Development of Some Science Concepts: a Replication of Piaget's studies with pupils in a New South Wales country high school". Unpublished B.A. (Honours) thesis, University of New England, Armidale, New South Wales, Australia. 1962.

WILK, R.E., EDSON, W.H. & JYI WU, J. "Student Personnel Research in Teacher Education". Review of Educational Research, Vol. 37, No. 3, (June 1967) p.219-232.

APPENDIX 1 : PIAGETIAN TASKS

Name _____ Group _____

Date _____ Interviewer _____

Stickman Task - proportional reasoning

1. Predicted height of Mr. Short: _____ small clips.

2. Justification for prediction.

Category	Description	Examples
___ I -intuitive	The explanation given does not make use of all the data, or uses the data haphazardly or illogically.	"I just thought Mr. Tall would be about 2 clips taller than Mr. Short". "I subtracted 4 from 6 and got 2. Then I added 2 to Mr. Short's height ..." etc. "If Mr. Tall is 6 large clips high, Mr. Short must be 3 large clips high". "Mr. Tall is 2 large clips higher than Mr. Short, so he must be two small clips higher".
____ A -additive	The explanation focuses on a single difference that is not co-ordinated with other differences. S may attempt to solve the problem by addition.	"Because 2 large clips are about equal to 4 small ones, I added 4 to the number of large clips". "If Mr. Tall is 6 large clips and Mr. Small is 4, the difference is 2. Since Mr. Tall is 9 small clips, I subtracted 2 and got 7 for Mr. Small's height".

Category	Description	Examples
____ Tr-transitional	The explanation shows only partial proportional reasoning, or S may refer to concrete comparisons or iterations.	"I laid out the paper clip chains on the table and could see that Mr. Small would be 6 small clips high". "I worked out how long a big clip is in little clips, then I counted how many paper clips it would take". "I divided 4 into 6 and got 1½. Then I added 1½ to 4 and got 5½". "4 is to 6 as 9 is to N". (Note the reversal of the size relationships. These Ss would otherwise have been classified R.)
____ R -ratio	The explanation uses a proportion or derives the scale ratio from the Mr. Tall/Mr. Short dimensions or the large clip/small clip relationship.	"1 large clip equals 1½ small clips, so 4x1½ equals 6". "Mr. Tall to Mr. Short is 6 to 4 large clips, so with small clips it will be 9 to 6, because that's the same ratio".

Colourless Liquids Task - combinatorial logical analysis.

1. Record the procedure used by the student to solve the problem by numbering the combinations below in the order they are attempted.

____ 1 + g	____ 1 + 2 + g	____ 1 + 2 + 3 + g
____ 2 + g	____ 1 + 3 + g	____ 1 + 2 + 4 + g
____ 3 + g	____ 1 + 4 + g	____ 1 + 3 + 4 + g
____ 4 + g	____ 2 + 3 + g	____ 2 + 3 + 4 + g
	____ 2 + 4 + g	
	____ 3 + 4 + g	____ 1 + 2 + 3 + 4 + g

2. Analysis of procedure. Tick (✓) the statements that apply:

____ 1. S made the colour in one way.

____ 2. S followed a logical sequence in making various combinations.

____ 3. S stated that 1, 3 and g are necessary to produce the colour.

____ 4. S stated that 2 did not help to produce the colour.

____ 5. S stated that 4 removed or prevented the colour.

____ 6. S achieved the colour in two ways.

3. Classification _____

ROLLING SPHERES TASK - CONSERVATION OF MOTION

		sequence	factors stated in predictions: weight	size	smoothness	launcher	air resistance		accuracy*	comments	factors given in explanations: weight	size	smoothness	launcher	air resistance	friction	comments
Glass marbles	VS																
	S																
	M																
	L																
Steel balls	S																
	M																
	L																
Wood spheres	VS																
	S																
	M																
	L																
	VL																
styrofoam plastic	S																
	M																
	L																
	VL																

* accuracy code: 0 - exact within 2 cm, + slightly over (>30cm), ++ much over (>30cm), slightly under (>30cm) much under (>30cm)

Analysis: Tick (✓) the statements that apply:

____ 1. S made fairly reliable and consistent predictions after only a few trials.

____ 2. S made fairly reliable and consistent predictions only after many trials.

____ 3. S discussed the causes of the cessation of motion as well as the causes of the ball's motion.

____ 4. S attempted to give a unified explanation, tying all the relevant factors together simultaneously.

Classification _____

APPENDIX 2

LOGICAL REASONING TEST

by

Gilbert M. Burney

Instructions

1. For most of the questions on this test you will need only to place a cross in the space on the answer sheet like this (X). For a few of the questions, you will be asked to give two or three answers. Instructions for answering these questions will be given when they appear in the test.

2. Several questions refer to diagrams and you should examine these diagrams closely before answering these questions.

3. If you have to change an answer, erase it completely and mark the new choice.

4. Try to answer all questions; if you are not sure of an answer, then choose the one that you think is most apt to be right.

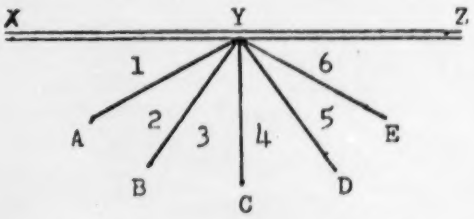
5. Think carefully before you answer each question.

6. Do not make any marks on this test booklet.

All Rights Reserved

1974

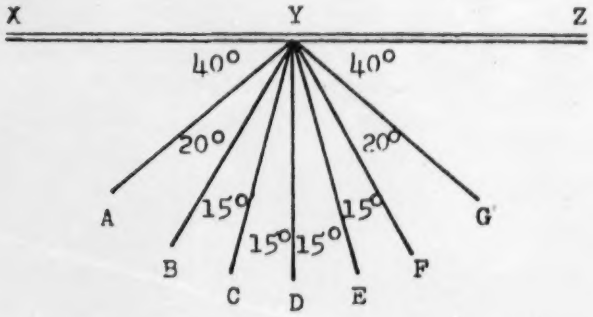
1. In the diagram below, the line XYZ represents a wall and a tennis ball is hit onto the wall so that it always hits at Y. Angle 1 equals angle 6, angle 2 equals angle 5, and angle 3 equals angle 4.



If a ball bounces from Y to B it must have been hit from:

(a) A (b) B (c) C (d) D (e) E

Here is a new diagram similar to the first one. Study it carefully and use it to answer questions 2 and 3.



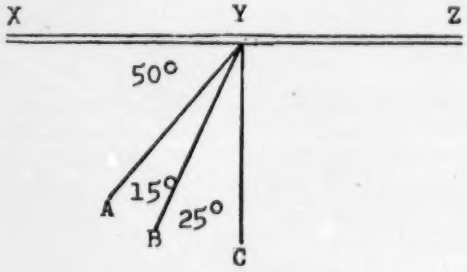
2. If a ball is hit accurately from B to Y on the wall, it will bounce to:

(a) A (b) E (c) C (d) F (e) G

3. If a ball bounces from Y to A it must have been hit from:

(a) A (b) E (c) C (d) F (e) G

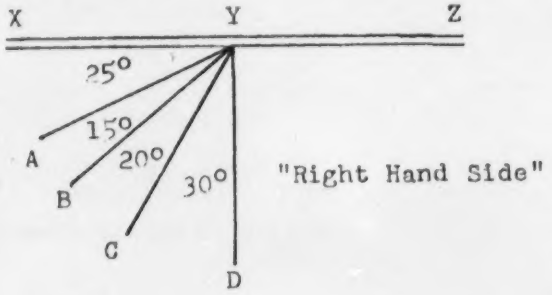
4. In the diagram below, a ball is hit from A to a point Y on the wall.



The angle the new path of the ball makes with CY is:

(a) 50° (b) 75° (c) 65° (d) 40° (e) 25°

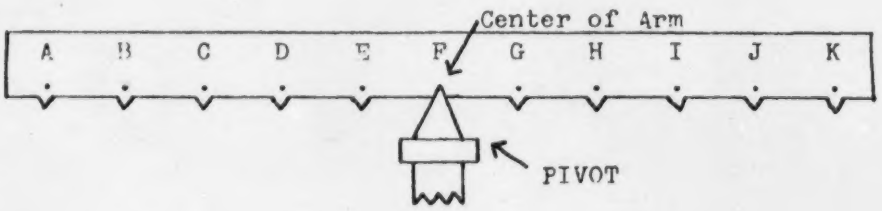
5. A tennis ball is hit from somewhere in the section marked "Right Hand Side" in the diagram below. The ball hits the wall at Y and bounces to C.



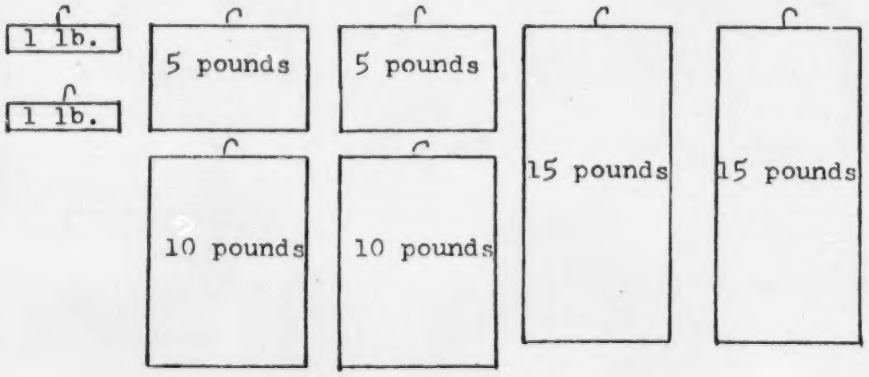
The size of the angle, from YZ, at which the ball must be hit is:

(a) 25° (b) 40° (c) 65° (d) 60° (e) 50°

Suppose you have a balance scale similar to the one in the diagram below. Study the diagram carefully. Questions 6-7 refer to it.



Weights which can be used:



6. A five pound weight is hung at D. To balance the arm again:

   (a) a one pound weight must be hung at A.

   (b) a ten pound weight must be hung at J.

   (c) a five pound weight must be hung at H.

   (d) a ten pound weight must be hung at E.

   (e) a five pound weight must be hung at K.

   (f) is impossible.

7. A five pound weight is hung at E and a ten pound weight at C. To balance the arm again:

   (a) a five pound weight must be hung at G and a ten pound weight at J.

   (b) a ten pound weight must be hung at H and a one pound weight at K.

   (c) a fifteen pound weight must be hung at I and a one pound weight at H.

   (d) a ten pound weight must be hung at I and a five pound weight at G.

   (e) is impossible.

   (f) a five pound weight must be hung at I and a ten pound weight at G.

Questions 8-10 are called syllogisms. Each syllogism consists of two premises and a conclusion. You are to determine whether each argument is valid or not.

Example:

P_1: No one year old babies can walk.

P_2: Paul is a one year old baby.

C: Paul cannot walk.

This is a valid argument.

- - - - - - - -

8. P_1: Not all R's are T's.

P_2: All T's are M's.

C: Some R's may not be M's.

(a) Valid (b) Invalid

9. P_1: All coal is white.

   P_2: All white coal produces red smoke when burning.

   C: Therefore when coal burns, the smoke is grey.

   (a) Valid (b) Invalid

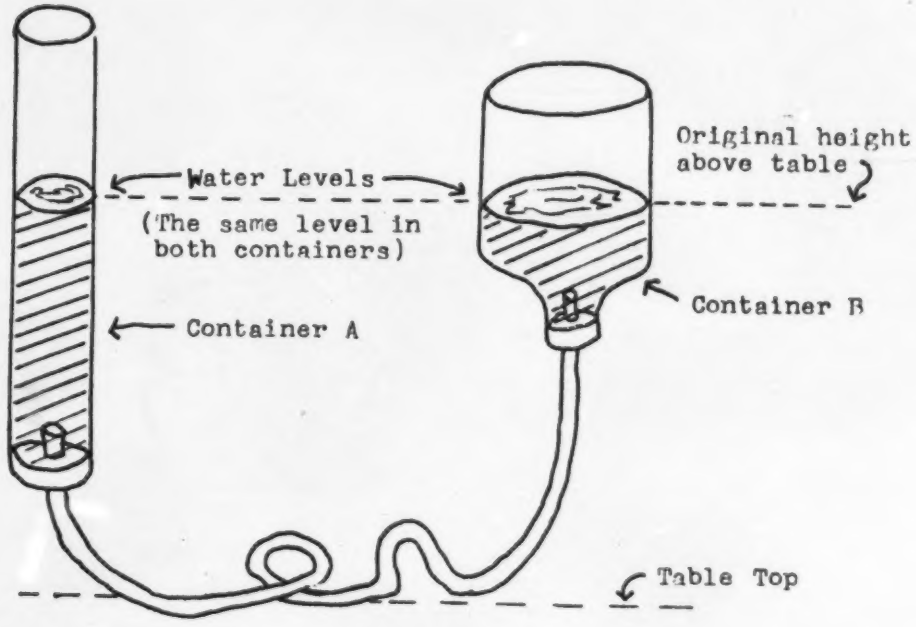
10. P_1: When John gets angry at Mary he hits her.

    P_2: John is not angry at Mary.

    C: Therefore John will not hit Mary.

    (a) Valid (b) Invalid

The diagram below represents two open-top containers with water in them. There is a length of hose connecting them that will allow water to pass from one container to the other. Container B has a larger diameter than container A. Use the diagram to answer questions 11 and 12.



11. The container A and the container B are moved down the same distance. The water levels in the containers will:

    (a) stay at the original height above the table.

    (b) change so that the level in A is above the original height above the table and the level in B is below.

    (c) change so that the level in B is above the original height above the table and the level in A is below.

    (d) change so that the levels in A and B are the same distance above the original height above the table.

    (e) change so that the levels in A and B are the same distance below the original height above the table.

12. Container A and container B are moved up the same distance. The water levels in the containers will:

    (a) stay at the original height above the table.

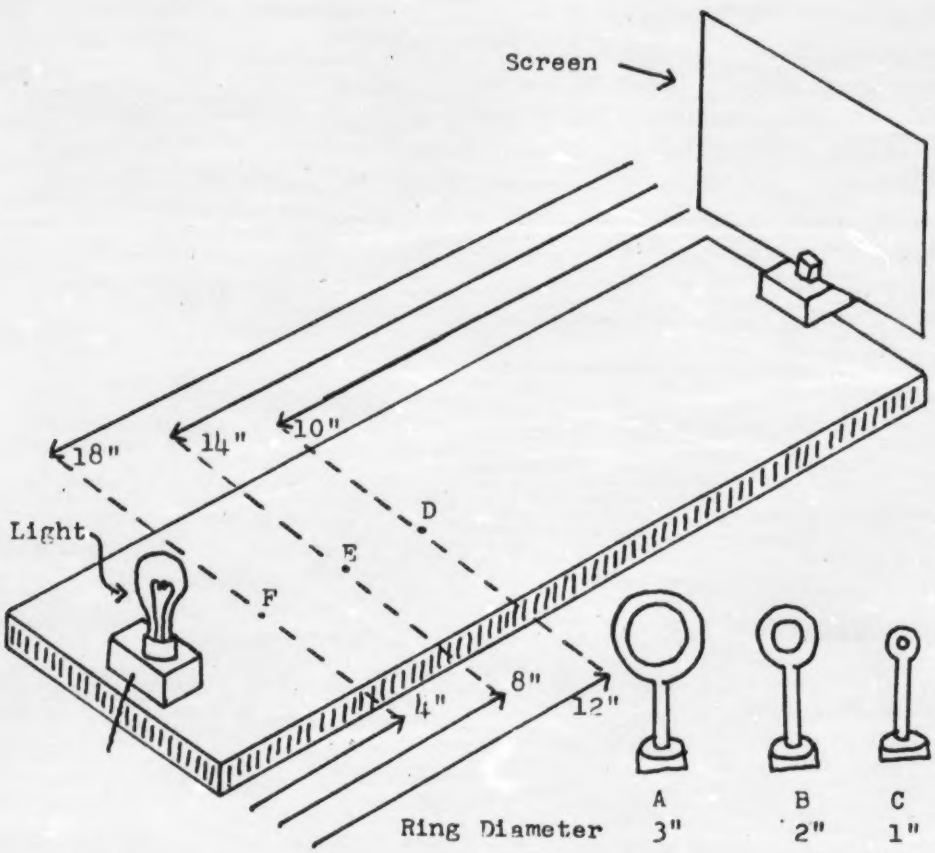
    (b) change so that the levels in A and B are the same distance below the original height above the table.

    (c) change so that the level in A is above the original height above the table and the level in B is below.

    (d) change so that the levels in A and B are the same distance above the original height above the table.

    (e) change so that the level in B is above the original height above the table and the level in A is below.

The apparatus pictured below can be used to throw shadows onto a screen. The rings pictured can be placed at points D, E, or F or anywhere along a line through D, E, and F between the light and the screen. The shadows that are referred to in the questions are the circular shadows of the rings only, not the ring stands. The distances of D, E, and F from the screen are indicated above and the distances of D, E, and F from the light are indicated below the apparatus. Study the diagram carefully and use it to answer questions 13-14.



13. The ring A is placed at D and its shadow allowed to fall onto the screen and the size of the shadow is measured. Ring A is removed and ring B is placed at D and the size of its shadow on the screen is measured. The two shadows formed:

(a) will be of equal size.

(b) will be of unequal size, the shadow of A being larger than the shadow of B.

(c) will be of unequal size, the shadow of B being larger than the shadow of A.

(d) will be of unequal size, the shadow of A being smaller than the shadow of B.

14 The ring B is placed at D and its shadow allowed to fall onto the screen and the size of the shadow is measured. Ring B is removed and ring C is placed at D and the size of its shadow on the screen is measured. The two shadows formed:

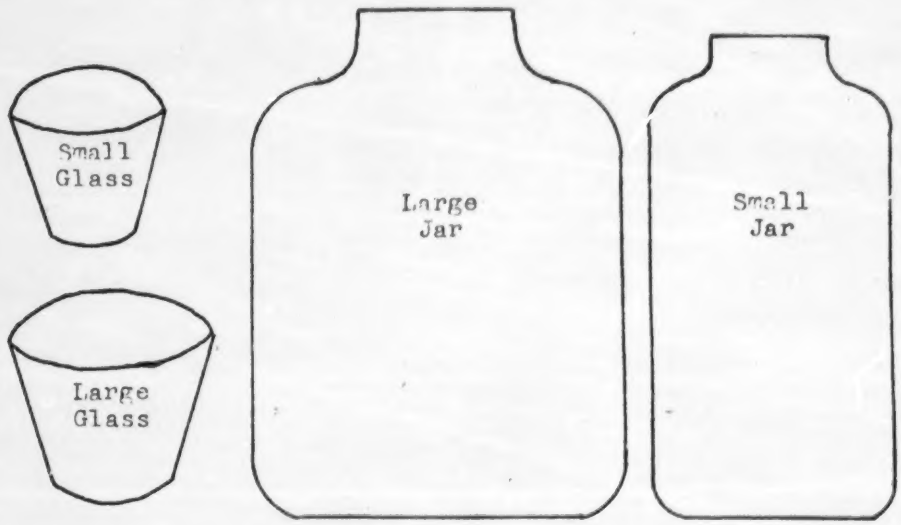
(a) will be of equal size.

(b) will be of unequal size, the shadow of B being larger than the shadow of C.

(c) will be of unequal size, the shadow of C being larger than the shadow of B.

(d) will be of unequal size, the shadow of B being smaller than the shadow of C.

The diagram below represents two glasses, a small one and a large one and two jars, a small one and a large one. Use this diagram for problem 15.



15. If it takes six large glasses of water or nine small glasses of water to fill the small jar and it takes eight large glasses of water to fill the large jar, then how many small glasses of water does it take to fill the large jar?

(a) 10 (b) 15 (c) 11 (d) 16 (e) 12

Questions 16-21 are verbal analogies. Verbal analogies consist of two pairs of words with each pair having the same relationship. In is to out as up is to down is an example of an analogy. The common relationship between in - out and up - down is that they are opposites. Order of the pair of words is also important. Peel is to banana as paint is to house is correct while peel is to banana as house is to paint is incorrect. In the following questions you are to choose two or three words that will best complete each analogy.

Example:

(a) tire			(e) anchor	
(b) motor			(f) deck	
(c) highway	is to car	as	(g) captain	is to ship
(d) map			(h) ocean	

In this example, the best choices to complete the analogy are highway and ocean resulting in the analogy: Highway is to car as ocean is to ship. In this case "operates on" is the common relationship, a car operates on a highway and a ship operates on the ocean. On the answer sheet the above question would be answered as shown below.

a	b	c	d		e	f	g	h
( )	( )	(X)	( )		( )	( )	( )	(X)

Be careful to mark all required answers for each question on the answer sheet. Some questions require two answers and some require three.

- 16 -

	(a) attempt		(e) problem	
	(b) completion		(f) chemical	
task is to		as		is to solution
	(c) work		(g) man	
	(d) question		(h) answer	

- 17 -

	(a) switch		(e) engine		(i) boat
	(b) wire		(f) canoe		(j) engine
light bulb is to		as		is to	
	(c) socket		(g) motor		(k) tractor
	(d) electricity		(h) steam		(l) paddle

- 18 -

(a) walk					(e) roll
(b) toe					(f) machine
(c) knee	is to	body	as	wheel	is to
					(g) bicycle
(d) foot					(h) spokes

- 19 -

(a) cow				(e) soldier		(i) bee
(b) horse				(f) swarm		(j) pig
(c) sheep	is to	flock	as	(g) pack	is to	(k) regiment
(d) foot				(h) litter		(l) wolf

- 20 -

(a) brain				(e) spring		(i) bedpost
(b) eye				(f) blanket		(j) ticking
(c) hat	is to	head	as	(g) caster	is to	(k) bed
(d) ear				(h) pillow		(l) summer

- 21 -

(a) music				(e) chair		
(b) house				(f) leg		
(c) bench	is to	piano	as	(g) eat	is to	table
(d) tuner				(h) furniture		